DARLING (E.A.)

THE EFFECTS OF TRAINING

A Study of the Harvard University Crews

BY

EUGENE A. DARLING, M.D.
CAMBRIDGE, MASS.

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THE EFFECTS OF TRAINING.

A Study of the Harvard University Crews.

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This investigation was undertaken at the suggestion of the Harvard Athletic Committee, by whom it was felt that a knowledge of the physiological changes occurring during severe training would be of value, and that incidentally data might be obtained throwing light on the obscure subject of overtraining. It is intended to make a similar study of the effects of training for several other forms of athletic contests besides rowing, especially foot-ball and running. Since no similar research had, as far as known, been attempted, this first series of observations on the effect of rowing was regarded as tentative. It was doubtful how far the subject would lend itself to study and hence it was thought best not to attempt too much until the more promising lines on which to work had been determined. Much of the work has been somewhat barren of result, while in other directions unexpected facts have been learned and the necessity for further study revealed. For example, it early became apparent that one of the most important parts of the investigation would concern the nutrition and tissue metabolism, but for want of suitable apparatus and in the absence of a chemist to analyze the food and excreta, this part of the work was done only in the most superficial way. It is hoped that a subsequent investi-

gation will include a much more complete study of these important points. The greater part of the work which was thought to be feasible this year was a study of the changes taking place in the heart and kidneys, and a series of observations on the weight and temperature and their relation to the general condition of the men. The observations covered the months of May and June, and hence included only the more strenuous part of the training period, for which all the men had been prepared by long preliminary work, as detailed below.

There were certain difficulties which limited the scope of the inquiry and which must be borne in mind in estimating the results obtained. The chief one was the impossibility of maintaining constant supervision over the men, and the consequent loss of much valuable information. This was not true, however, during the two weeks at New London, where the opportunities for observation were excellent. A second difficulty was that circumstances sometimes compelled the use of cruder methods of examination than would be necessary for the most accurate work. For instance, the most accurate method of determining the size of the heart and the method least liable to error from the "personal equation" is by means of the fluoroscope, but owing to the impossibility of setting up an elaborate x-ray machine at New London, one had to fall back on the less certain method of combined auscultation and percussion aided by the phonendoscope. A third limitation to the inquiry was the obvious one that all the observations had to be arranged so as not to interfere in any way with the main objects of the training, which were to learn to row and to get into the best possible condition. Consequently, nothing in the way of experiment could be attempted nor any examination which would fa-

tigue the men or distract their attention from their rowing.

These limitations were unavoidable, but were counterbalanced in a way by the active co-operation of the coach and of the individual members of the crews. Their courtesy and interest were unfailing and alone made it possible to carry on the observations, involving as they did a considerable expenditure of time and a certain amount of irksomeness.

Preliminary training. — The large number of candidates who began training in the winter were gradually weeded out by a process of natural selection, based on numerous trial races, until but sixteen remained. These men were organized into two crews late in April, and practised daily until early in June. Shortly before going to New London a new man was taken from one of the Weld crews, and five of the squad were dropped. The remaining twelve comprised the two crews — the eight-oar and the four-oar — which took part in the races, and most of the statistics of this paper refer to them. The observations on the five who stopped training early in June were eliminated, so that more accurate comparison could be made.

Of these twelve men all had done considerable previous rowing in their class crews or in the Weld crews. Four had rowed on former Varsity crews and one had been a substitute. Several had begun rowing in preparatory schools. Six out of the twelve had played football and two had practised running. The period of active training for these sports had been from two to six years, so that all the men may fairly be called trained athletes, and the changes effected by training would not be expected to be as marked as in the case of inexperienced men.

The previous health of all the men had been good

with one exception, who gave a history of typhoid six years ago and rheumatism a year later.

General statistics. — The following table gives in brief the ages, weights, heights, chest and abdominal measurements and vital capacities of the lungs of the individual members, with averages for the eight and four, and, finally, the averages for the entire squad:

TABLE I.

No.	Age.	Weight May 8–17.	Height.	Chest measurements.			Circum. of abdomen.	Vital capacity. Cu. ins.
				Inspiration.	Expiration.	Expansion.		
1	20	165	5′ 9″	41″	35″	6″	31″	335
2	20	158½	5′ 11½″	38″	34″	4″	29″	290
3	20	175½	5′ 9½″	41″	37″	4″	33″	330
4	20	180	6′ 1½″	39¼″	35″	4¼″	31½″	330
5	21	177½	6′ 2″	40¾″	37¼″	3½″	32¾″	380
6	19	178	6′ 2½″	39¼″	33¾″	5½″	31″	330
7	24	167½	6′ 1½″	37¾″	33¾″	4″	30″	330
8	21	163	6′ 1″	39¾″	34½″	5¼″	31″	350
Average of eight.	20⅝	170⅝	6′ 0¼″	39⅝″	35″	4⅝″	31⅛″	334
9	20	159½	5′ 8½″	38″	34¾″	3¼″	31½″	295
10	21	176	6′	42″	37″	5″	33″	380
11	21	170	5′ 10½″	38¼″	34¼″	4″	32″	260
12	22	157	6′	39¼″	34¾″	4½″	31″	290
Average of four.	21	165⅝	5′ 10¾″	39⅜″	35 3-16	4 3-16	31⅞″	306
Average of squad.	20¾	169	5′11¾″	39½″	35″	4½″	31½″	325

I. GENERAL SKETCH OF THE TRAINING.

Daily rowing. — During May and the first ten days of June the daily exercise consisted of rowing on the Charles in the latter part of the afternoon.

The distance covered varied according to circumstances from five to eight miles, occasionally more. At New London there was added a short morning row of two to four miles. Between the middle of May and the race there were five time-rows — three on the Charles of three and three-eighths miles each, and two on the Thames over the four-mile course. These time-rows were designed to accustom the men to rowing long distances at high speed and to enable the coach to judge of their form and endurance, but incidentally they afforded excellent opportunities to study the effects of long-continued exertion, and were, moreover, striking demonstrations of the effects of training. The earlier time-rows, though shorter than the later ones, were much more exhausting, and their effects on the hearts and kidneys — the organs showing most evidence of strain — were considerably greater.

For the purposes of this inquiry, however, the time-rows had to be regarded as factors disturbing the regular process of development which might be expected were the daily exercise uniform or slowly increased, and hence it became necessary to divide the observations into two parts, the first directed to the changes in the daily condition, eliminating the effects of the time-rows as far as possible, and the second directed to the immediate effects of the time-rows.

Diet. — The diet allowed was a very generous one, consisting of a hearty breakfast at 7.30, lunch at one and dinner after the evening row. For breakfast the fare consisted of fruit, oatmeal or shredded wheat, eggs, some form of meat, bread and butter, potato and milk. At noon there was cold meat, potato, bread and butter, marmalade, preserved fruit and milk. Dinner comprised soup, occasionally fish, roast beef or some other hot meat, several vegetables, bread and butter and a simple dessert. No tea or coffee was

allowed, but ale or claret was permitted at dinner, also water in small amounts as desired. During the last week before the race each man received a dish of calves'-foot jelly with sherry wine after the morning row, and a light lunch of oatmeal, milk and bread was served at four o'clock in the afternoon.

Sleep, bathing, etc. The ordinary allowance of time for sleep was nine hours, from ten to seven. General plunge baths were prohibited, but after rowing the men were allowed a cold shower bath in Cambridge and a bucket bath (for want of a shower) at New London.

Besides rowing the men indulged in very little exercise. While at New London a five-minute walk before breakfast, an occasional game of quoits or spasmodic efforts to play baseball were the only other forms of exercise indulged in. When not rowing, sleeping or eating the men passed the time in reading, writing or in pure and simple loafing.

II. EFFECTS OF TRAINING.

Weight. — It has long been recognized by athletic trainers that the weight is one of the best indicators of condition. The average weight of the eight men constituting the crew from May 18th to June 29th is shown in Chart I.

During the first ten days of this period there were no marked variations, and in spite of two hard time-rows the average on May 29th was exactly the same as on May 18th, 171.4 pounds. Beginning May 30th, when there was a third time-row, there was a steady fall in weight for a week. The weather at this time was very hot and oppressive, and owing to the fact that the crew rowed for a few days on Spy Pond, Arlington, there was much delay in getting dinner. These two factors, added to the hard work the men

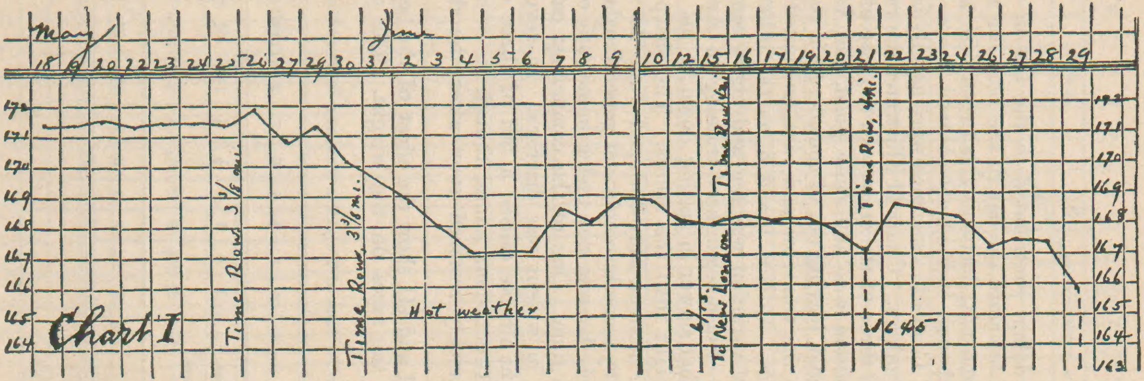

CHART I. Average Daily Weight of Varsity Eight.

were then doing, contributed to the fall in weight. From June 6th until the day of the race the average was very constant, fluctuating between 167 and 169 pounds, although individuals showed more or less variation. Losses in some men were usually balanced by gains in others. Chart II illustrates the range of variation in three of the crew. In the case of No. 7, whose condition was uniformly good, the variation was slight and, leaving out of consideration the sharp fall during the time-row and race, amounted to but three pounds. In Nos. 6 and 3, on the other hand, the range of variation was ten and eight pounds respectively. No. 6 began hard training in April and was somewhat slower in getting down to his normal training weight than the others. The sharp fall in No. 3's line between May 30th and June 2d was accompanied by some insomnia and general malaise, but unfortunately he was not under immediate observation at the time. One of the commonest causes of fluctuation in weight was diarrhea. In several instances slight attacks caused a fall of three or four pounds in twenty-four hours, though in every case this was quickly restored soon after the diarrhea ceased.

Tables II and III show the effect of the last time-row and of the races on the weight. The prelimi-

TABLE II. Loss of Weight in Time-row of June 21st.

	1	2	3	4	5	6	7	8	Total.	Average.
Preliminary loss.	1	1	0	1	1	¼	½	1½	6¼	¾+
Loss during time-row.	1¾	2½	2¾	4	2	2¾	3	2	20¾	2⅝−
Total loss.	2¾	3½	2¾	5	3	3	3½	3½	27	3⅜

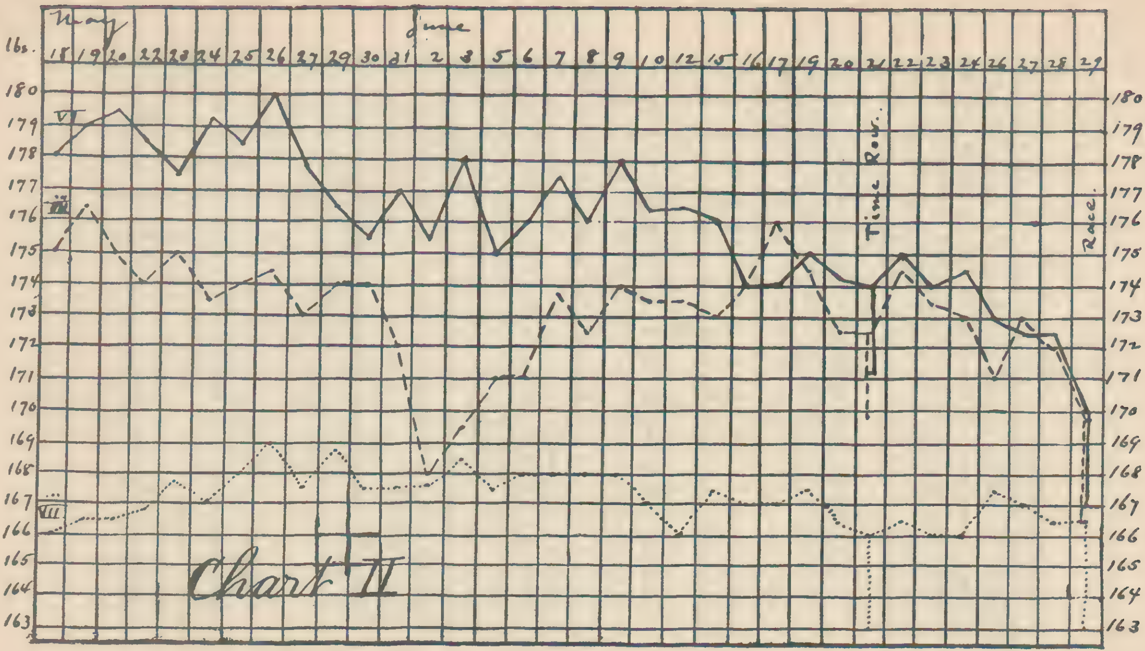

CHART II. Weight Chart of Nos. 3, 6 and 7, showing Daily Variations.

nary loss means that which is always noticed during the twenty-four hours before a race. It may be attributed to nervousness, affecting the appetite and urinary secretion. This preliminary loss, as might be expected, was considerably greater before the race than before the time-row, being $12\frac{1}{4}$ and $6\frac{1}{4}$ pounds respectively, while the actual losses during the time-

TABLE III. Loss of Weight in Race, June 29th.

	1	2	3	4	5	6	7	8	Total.	Average.
Preliminary loss.	2	$1\frac{3}{4}$	$2\frac{1}{4}$	$\frac{1}{2}$	1	$2\frac{1}{2}$	0	$2\frac{1}{2}$	$12\frac{1}{4}$	$1\frac{1}{2}+$
Loss during race.	$2\frac{1}{2}$	2	$3\frac{1}{4}$	3	2	3	$3\frac{1}{2}$	$2\frac{3}{4}$	22	$2\frac{3}{4}$
Total loss.	$4\frac{1}{2}$	$3\frac{3}{4}$	$5\frac{1}{2}$	$3\frac{1}{4}$	3	$5\frac{1}{2}$	$3\frac{1}{2}$	$5\frac{1}{4}$	$34\frac{1}{4}$	$4\frac{1}{4}+$

row and race were nearly the same, $20\frac{3}{4}$ and 22 pounds respectively.

Through an oversight, the weights of the Varsity four-oared crew were not recorded during the last two weeks of training. A comparison of their weights immediately before and after the two-mile race showed an aggregate loss of 13 pounds, averaging $3\frac{1}{4}$ pounds.

TABLE IV. Twenty-four-hour Gain after Time-row of June 21st.

	1	2	3	4	5	6	7	8	Total.	Average.
Total loss.	$2\frac{3}{4}$	$3\frac{1}{2}$	$2\frac{3}{4}$	5	3	3	$3\frac{1}{2}$	$3\frac{1}{2}$	27	$3\frac{3}{8}$
Gain in 24 hours.	$4\frac{1}{4}$	5	$4\frac{3}{4}$	$5\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$33\frac{1}{2}$	4 3-16
Net Gain.	$1\frac{1}{2}$	$1\frac{1}{2}$	2	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$	0	0	$6\frac{1}{2}$	13-16

Compensating for the rapid loss before and during the time-rows and races, there was noticed after those events an equally rapid recuperation; this is shown in Table IV, in which are given the total losses and corresponding gains for the time-row of June 21st. Every man recovered all or more than he had lost inside of twenty-four hours.

A loss of several pounds during prolonged exertion does not by any means imply an undue degree of exhaustion, provided the individual is in good condition. The men who lost most were in fully as good condition as their companions both before and after the race. It is generally accepted on experimental grounds that during active exercise the energy is largely if not wholly derived from the oxidation of fat and glycogen, and that the muscles themselves are not used up in the process. The end products of this combustion — chiefly water and carbon dioxide — are rapidly excreted through the lungs and skin. The loss of weight represents very closely, therefore, the amount of fuel used up. Hence the man who has an adequate supply of reserve fuel in the form of fat and glycogen is in better condition to withstand a prolonged exertion than one who is deficient in those substances. This corresponds with the experience of all athletes. There is always a loss of weight during the early part of training, while a man is getting rid of superfluous fat, but every athlete knows that when a certain point is reached — his so-called "weight in training" — any further reduction is accompanied by a feeling of lassitude and an incapacity to sustain prolonged exertion without excessive fatigue. This form of over-training, known as "staleness," is in all probability due to a deficiency of reserve fuel. These facts emphasize the importance of maintaining at a proper proportion the fat and carbo-

hydrate constituents of the diet instead of sacrificing them for an excess of nitrogenous material — a mistake which is undoubtedly often made, and which will be discussed more in detail later.

Temperature. — The temperatures were taken in the mouth twice daily, at 8 A. M. and 9.30 P. M., dur-

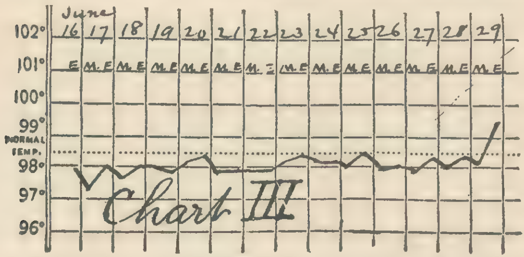

CHART III. Temperature Chart of Entire Squad.

ing the last two weeks of training. The chief points brought out by the routine readings were the great variation in individual cases and the persistent tendency to subnormal temperatures. The average for the entire squad remained near 98° F., as shown in Chart III.

A few individuals maintained approximately a normal average of 98.5°, but the majority showed wide variations. It was not uncommon to find a temperature of 96° in the morning and 98° or more in the evening in the same man. Charts IV and V are fair sample charts.

The individual variations could not be shown to have any definite relation to the general condition beyond the coincidence that those men who varied most in weight also varied in temperature. The body temperature is dependent on so many circumstances

that variations within limits are to be expected. The heat production during muscular and other metabolic action is constantly balanced by the heat loss in warming the expired air, the urine and feces, by evaporation of perspiration and by conduction and

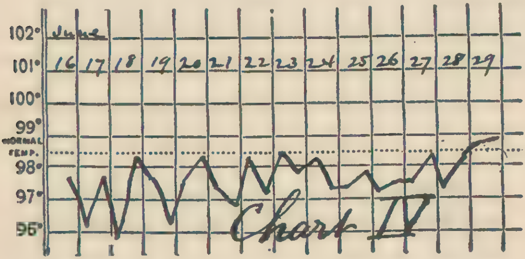

CHART IV. Temperature Chart of No. 8.

radiation from the skin. During training the greater part of heat production by muscular action (supposed to be its main source) is confined to a comparatively brief portion of the twenty-four hours and during that same portion the heat loss is also great. It is not surprising that the heat balance is not stationary and the charts show that in fact in the majority of cases it is not maintained at a fixed point.

On the day of the races the temperatures were taken three times, first, at 8 A. M., second, while the men were dressing for the race, and finally, from ten to fifteen minutes after the race while returning to the quarters in the launch. There was an average preliminary rise in temperature, corresponding to the preliminary fall in weight, amounting to about 1.5° F., followed by a slight rise of .2° during the four-mile

race. In the case of the four-oared crew the average preliminary rise was .7° and a further rise during the two-mile race of .7°. A glance at the Table (V) shows that on the whole those men who had the greatest preliminary rise had either a stationary or falling temperature during the race (Nos. 2, 4 and 5). The other extreme was seen in No. 9, who had a preliminary rise of only .2° and a rise during the race of 2.6°. In several instances the net variation was very slight.

It was hoped that the temperature observations

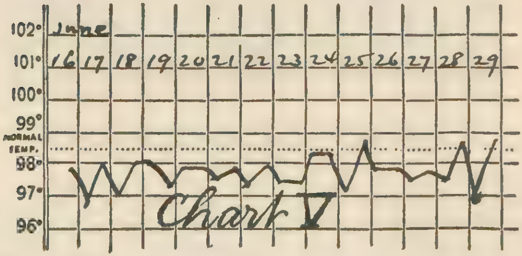

Chart V. Temperature Chart of No. 4.

would throw some light on the remarkable results obtained by Drs. Williams and Arnold in their observations of the Marathon runners.[1] They found a uniform drop during that race (a 25-mile run) of 2° to 5½°. That race, however, was run in the middle of April at a temperature of 44° F. and against an easterly wind — the conditions all favoring rapid cooling by conduction and evaporation. Furthermore, the temperatures were all taken in the mouth

[1] Philadelphia Medical Journal, iii, 1,233.

TABLE V. Variations in Temperature during Races.

	Varsity Eight.								Varsity Four.					
	1	2	3	4	5	6	7	8	9	10	11	12	Av. of 8.	Av. of 4.
Temperature at 8 A. M.	97.8	97.7	98.3	96.6	97.6	99.0	99.0	98.6	97.0	98.4	98.3	98.4	98.1	98.0
Temperature before race.	99.2	100.0	99.2	98.6	99.7	100.6	100.2	98.9	97.2	98.7	99.8	99.2	99.55	98.73
Temperature after race.	100.7	98.7	100.3	98.7	99.4	100.6	100.2	99.2	99.8	98.4	100.2	99.3	99.73	99.43
Preliminary rise.	1.4	2.3	0.9	2.0	2.1	1.6	1.2	0.3	0.2	0.3	1.5	0.8	1.5	0.7
Variation in race.	+1.5	—1.3	+1.1	+0.1	—0.3	0.0	0.0	+0.3	+2.6	—0.3	+0.4	+0.1	+0.2	+0.7
Total variation.	+2.9	+1.0	+2.0	+2.1	+1.8	+1.6	+1.2	+0.6	+2.8	0.0	+1.9	+0.9	+1.7	+1.4

and after nearly three hours of rapid breathing of air at 44° F. it is not unreasonable to assume that the mouth cavity may have been cooler than the body generally. One cannot accept as proved their assertion that after prolonged exertion the temperature is invariably lowered. It is the same with their implication that a subnormal temperature during training means "staleness." This idea was apparently based on the single observation that the temperature of one of the contestants was 97.5° before and 97° after a practice run; that the man was advised to rest and to partake of more carbohydrates; that on the morning of the race his temperature was 98.2°, and finally that he was among the winners. This observation proves nothing except that a rest and some carbohydrates are good things before a race. The temperature variation was quite within normal limits. If subnormal temperature means overtraining, then nearly every man in the Harvard crew squad was overtrained at one time or another during the last two weeks before the races, a statement which certainly would not be borne out by the other facts in their condition nor by the vigor which they all displayed during the last time-row and especially during the races. The rise of temperature observed just before the races certainly did not mean a rapid recovery from a condition of "staleness," but simply indicated that for some reason, probably a nervous one due to excitement, the heat production was greater than the heat loss. During the boat races, which were rowed on a clear, sunny day at a temperature of about 80° F. and low humidity, the conditions were favorable for rapid heat loss by perspiration and radiation, so that the excessive heat production which, according to all physiological experience, must have taken place was readily dissipated and the temperature balance maintained.

On the whole we must admit that a subnormal temperature, while of possible significance, cannot yet be regarded as a positive proof of overtraining.

Circulatory system. — Periodic examinations of the heart and pulse were made, special attention being given to the size of the heart, to the occurrence of abnormal sounds and to the rate and character of the pulse. Examinations were also made after several time-rows and both races.

Inspection of precordia, etc. — All of the men showed a prominence of the precordial region and a more diffuse pulsation than normal. The apex beat when visible was usually located in the fifth intercostal space, just inside the mammillary line. After the time-rows and races the apex beat was visibly displaced to the left, and in many instances a marked precordial and epigastric pulsation was noted. There was also in most cases visible pulsation in the peripheral arteries, most marked in the subclavians and carotids. The color was uniformly good, there being no instances of noticeable pallor or cyanosis, in spite of considerable disturbance of the heart's action in some cases.

Size of heart. — The routine examinations were all made in the middle of the afternoon, before rowing, so that the hearts might have recovered as far as possible from the rowing of the day before, and might be taken at their minimum size. Further examinations were made after the time-row of June 21st and after the races. The method pursued was as follows. The heart sounds were first examined and the apex beat located with the man standing. The man then lay flat and the apex beat was again located by sight and auscultation. Then, by combined auscultation and percussion, using the phonendoscope, the right, left and upper borders were found and outlined. The

method is open to objection, as already stated, but seemed to be the most accurate under the circumstances, and by considering averages it was hoped that individual errors might, to a certain extent, be eliminated. The outlines were transferred to tracing cloth, the position of the nipples marked and the chart then made was kept for comparison. In measuring variations it was found that two fixed lines were necessary, one connecting the nipples — the intermammillary line — and the other bisecting the first at right angles — the median line of the chest. The ordinary terms employed clinically giving the position of the borders in relation to the sternum, ribs, or nipples are so variable in different individuals that no mean can be determined. The position of the apex beat was measured both from the median line and the intermammillary line; the right and left borders were measured from the median line, the former at the level of the nipples, the latter at the apex. The upper border was measured from a line drawn through the apex parallel to the intermammillary line. By averaging these various measurements it was easy to construct a chart representing the average heart of the squad and also to estimate the average variation.

The following Table (VI) and Chart (VI) give the measurements and variations of the average heart of the entire squad. They show that there was a progressive enlargement affecting both sides of the heart during May and reaching its maximum early in June. After this there was a considerable shrinkage, especially of the left side, both the left border and the apex beat receding towards the median line until their positions were not very different from those of early May. The right side of the heart also showed shrinkage but to a less degree than the left. The position of the upper border varied considerably in

the different examinations, depending apparently partly on the fulness of the stomach and partly on the depth of respiration. The relative rise and fall of the apex beat could not be followed as closely as its lateral movement, owing to the ribs.

The period of greatest enlargement corresponded to the period of the most arduous work, late in May and early in June, when the final selection of men was being made, and when consequently every man was pulling his hardest. Probably the individual

TABLE VI. **Average Heart Measurements of Squad.**

Dates of examinations.	Men examined.	Apex beat.		Right border, cm.	Left border, cm.	Total breadth, cm.	Upper border.	
		From median line, cm.	From intermam. line, cm.				At middle point, cm.	At quarter point, cm.
May 9–17 . . .	11	8.5	4.5	3.9	12.0	15.9	5.6	3.9
May 18–26 . . .	11	9.0	4.4	5.1	12.8	17.9	6.6	4.4
June 2–8 . . .	12	9.7	4.9	6.0	13.2	19.2	6.0	3.8
June 17. . . .	12	9.9	5.3	5.7	12.9	18.6	5.0	3.2
June 29 before race.	12	9.5	5.0	5.8	12.3	18.1	5.5	3.8

strain was greater at this time because the crew had not yet learned to pull as a unit. Then too, as already mentioned, the weather was very unfavorable, and the effort required to do the work was considerably greater than was needed later. The better weather conditions prevailing at New London, the more uniform rowing as the form of the crew was perfected and the more accurate adaptation of each man's rigging to his peculiarities, all tended to lessen

the strain on the individual oarsman and by enabling him to do his work with less muscular effort proportionately diminished the labor demanded of the heart.

How much of the enlargement was due to hypertrophy and how much to dilatation is difficult to say. Probably there were both hypertrophy and dilatation. The accompanying change in the heart sounds in certain cases to be described later would indicate that there was considerable dilatation at first, but that sub-

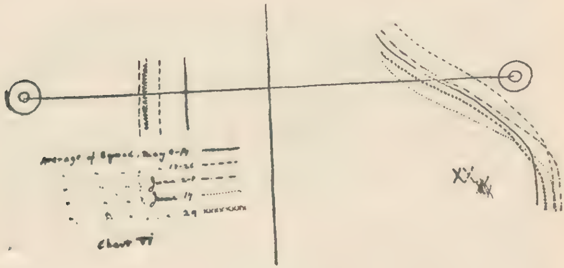

CHART VI.

sequently the hearts gradually recovered tone and a true compensatory hypertrophy took place.

During the races, both four-mile and two-mile, a considerable dilatation took place, as shown in Charts (VII) and (VIII). The average increase in breadth of the cardiac dulness was nearly the same in the two crews — 1.4 centimetres for the eight and 1.5 centimetres for the four. The marked rise of the upper border relative to the intermammillary line may be attributed to the fact that the examinations after the race were unavoidably delayed until after dinner, and consequently allowance must be made for the full stomach.

Heart sounds. — The twelve men in the squad may be divided into three groups according to the effect of the training and races on their heart sounds and action.

In Group I, numbering five men, may be placed those whose hearts developed no markedly abnormal condition. The pulse rate at rest varied from 60 to 80, and after the time-rows and races, rose to 120 or thereabouts. The sounds remained normal, except that the first sound became somewhat louder and rougher than normal. Both the first and second sounds were occasionally reduplicated.

In Group II, including two men, the routine examination showed nothing abnormal, but after the time-rows and race both developed a faint blowing systolic murmur, loudest at the left margin of the sternum in the second and third intercostal spaces, but also audible at the apex. As in Group I, there was some tendency to reduplication of the sounds, but the rhythm remained normal.

In Group III may be placed the remaining five men, whose hearts showed abnormalities of sound or action at several different examinations, both before and after unusual effort. The most extreme case deserves a detailed description. This man had had rheumatism and typhoid and had been informed several years before that his heart was weak.

Following are the notes as taken:

May 10th. Pulse 96; irregular. Diffuse precordial and epigastric pulsation; pulmonic second sound accentuated; blowing systolic murmur audible over entire cardiac area, loudest in pulmonic area and at apex.

May 18th. Pulse 84; irregular; heart sounds as above but murmur inaudible at apex.

May 25th, after time-row of $3\frac{3}{8}$ miles. Pulse 138; very irregular; two sounds of equal intensity at

apex; rhythm embryonic; murmurs very loud over entire precordia.

May 30th, before time-row. Pulse 84, somewhat irregular; murmur faint. After time-row of $3\frac{3}{8}$

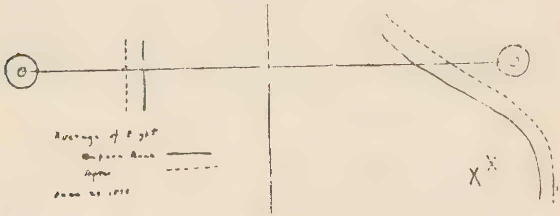

Chart VII.

miles. Pulse, 128; fairly regular; murmur much fainter than after previous time-row.

June 7th. Pulse 88; sounds as before time-row of May 30th.

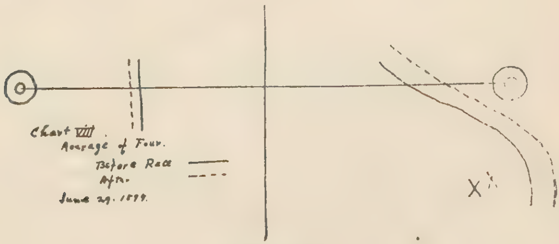

Chart VIII.

June 17th. Pulse 78; regular; murmur very faint.

June 21st. Pulse 82; regular; no murmur. Two

hours and a half after four-mile time-row. Pulse 98; regular; no murmur.

June 29th, before race. Pulse 84; regular; no

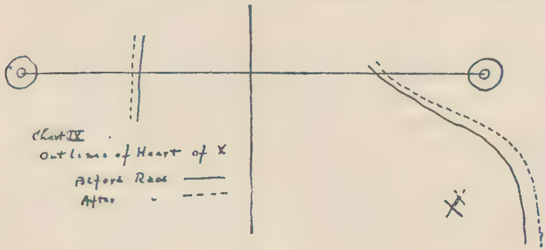

CHART IX.

murmur. Three hours after race. Pulse 88; murmur audible but very faint. General condition excellent.

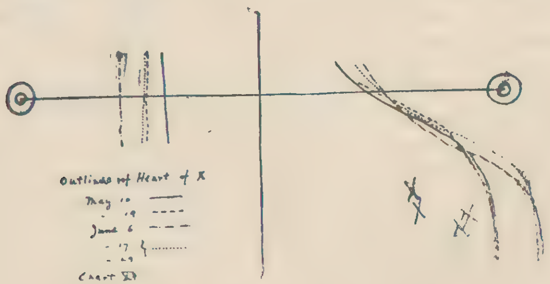

CHART X.

The changes in the size of this heart corresponding to the changes in sounds and action are shown in Chart X, while the comparatively slight increase during the race itself is brought out in Chart IX.

The gradual improvement in this heart was one of the most instructive points in the entire investigation. After the time-row of May 25th it was in bad shape. The irregularity, accentuated pulmonic second sound, embryonic rhythm and rapid action, together with the enlargement, which was well marked, all pointed to an acute dilatation. During June the establishment of a compensatory hypertrophy was indicated by the return to normal rhythm and rate, the practical disappearance of the murmur and the stationary size. With all the disturbance shown by examination of this man's heart, there was nothing in his appearance or capacity for work which would have called attention to his heart. If he had been advised to stop rowing when his heart was first examined the best demonstration of the beneficial effects of training would have been missed and the crew would have lost a very valuable man.

The four other hearts in this group showed much the same conditions, though in a less degree. All finished the race in good condition and without any more exhaustion than their companions.

Pulse. — The character and rate of the pulse have already been mentioned in several instances, and it is only necessary to add that it was invariably of high tension after unusual effort. There was no confirmation of Williams and Arnold's observation of diminished tension in the Marathon runners. It is possible that the exhaustion of the latter was extreme, and their hearts may have been much more affected than was the case with the crews. It is to be regretted that circumstances forbade the taking of sphygmographic tracings.

The cause of the murmur in acutely dilated hearts is ably discussed by Williams and Arnold; no evidence was secured in this study opposed to their con-

clusion that the bruits are of mitral origin and are due partly to a relaxation of the circular muscular fibres surrounding the orifice and partly to fatigue of the papillary muscles which control the movements of the valve-cusps.

The chief deduction to be made from this study of the hearts is that the heart is a muscular organ and that it shows with the other muscles both the fatigue due to violent and prolonged exertion and also the increase in size and power due to proper exercise and nutrition. The fatigue results in dilatation, the increased power in hypertrophy, and one of the main objects of training is the establishment of this hypertrophy. The physiological capabilities of the heart are enormous, and in judging of the effect of any undue exertion on it we must not regard the murmurs and irregularity alone, but must also consider carefully the way in which the heart is doing its work, its strength, as shown by its ability to maintain a proper arterial tension, and its recuperative power. As with other muscles, not size but quality tells in the long run.

Kidneys. — Periodic examinations of the urine were made coincidently with the heart examination. An attempt was made to estimate the twenty-four-hour amount, specific gravity, urea percentage and total urea, to test for albumin and sugar and to examine the sediment microscopically. The figures given below, as far as they refer to the twenty-four-hour amount and calculations based thereon, are probably considerably less than they should be. Even with the best intentions, slips of memory were liable to occur, and the full amount of urine passed was not always saved. Perhaps ten to twenty per cent. should be added to the urea excretion for this reason.

The urea was estimated by Squibb's ureometer.

For albumin both the nitric-acid and heat tests were employed, and in case of doubt the picric-acid test was resorted to. When an appreciable amount was found, Esbach's albuminometer tube was used. The sugar test used was Fehling's.

The main facts ascertained are summarized in Table VII, subject to correction as noted above. These figures denote a moderate increase in the urea secretion above the normal and by implication a moderate increase in nitrogenous metabolism, but by no means as great an increase as one would expect if all

TABLE VII. Average Urine Tests.

Date.	No. exam.	24-hour amount.	Specific gravity.	Urea, %	Total urea.
May 9–17 . . .	11	1181 c. c.	1.028	3.42	39 5 gms.
May 18–26 . . .	11	1396 c. c.	1.027	2.68	36.9 gms.
June 2–8 . . .	12	1028 c. c.	1.027	2.76	27.3 gms.
June 18	12	1403 c. c.	1.022	2.53	34.2 gms.
June 20	12	1374 c. c.	1.024	2.66	36.3 gms.

the proteids eaten were absorbed and utilized. Physiologists have proved that an increase in the urea elimination above normal limits is usually caused by an increase in proteid digestion and not by an increase of muscular action.

Sugar. — The tests for glucose were invariably negative.

Albumin. — An unexpected fact brought out in the routine examination was the presence of traces of albumin in the urine of a large proportion of the squad under ordinary conditions of training. The twenty-four-hour amounts were examined six times, the tests

being made intentionally only after a lapse of several days after the time-rows, to eliminate their effects as far as possible. In 83 specimens examined albuminuria was present 48 times. The amount of albumin was never more than a trace.

Sediments. — The albuminuria was, with but few exceptions, always accompanied by renal casts and epithelium and occasionally by a considerable excess of leucocytes. In several instances a few casts were found in urines which gave negative albumin tests. In the few cases of albuminuria without casts partial decomposition had taken place before the microscopic examination, so that casts may have been present but obscured.

Albuminuria after time-rows and races. — After three of the time-rows and after both races the first urine passed was examined for albumin and casts. The specimens were all small in quantity — one to three ounces — highly concentrated, and invariably contained considerable amounts of albumin, as shown in Table VIII. The largest percentage observed (0.9 per cent., Esbach) was in the urine of one of the four-oared crew after the two-mile race. The sediments contained correspondingly large numbers of hyaline and finely granular casts, many having renal cells and red blood corpuscles adherent. In many of the sediments there was also a considerable number of red blood corpuscles and an excess of leucocytes. The sediment in many cases was exactly that of the first stage of acute nephritis, and if examined without a knowledge of the conditions might easily have caused anxiety.

To find out how long the albuminuria and casts continued after the time-row of May 30th single specimens were examined the following day before the afternoon row, with the result that of 14 samples

TABLE VIII. Albuminuria after Time-rows and Races. Figures Represent Percentages by Esbach's Albuminometer.

		Varsity Eight.								Varsity Four.				Substitutes.				
Date.	Occasion.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
May 25	Time-row.	Trace	....	0.12½	0.12½	0.12½	0.12½	Trace	0.25	0.25	0.25	0.12½	0.25	0.12½	....	Trace	0.12½	Trace
May 30	Time-row.	0.08	....	0.38	0.05	0.12½	0.10	0.05	0.15	0.05	0.15	0.05	0.05	0.05	0.10	Trace	0.05	0.05
June 21	Time-row.	Trace	Trace	0.25	Trace	0.05	0.07½	0.07½	0.07½	....	...	....	....	...	....	....	....	....
June 29	Races.	....	0.07½	0.25	0.10	0.05	Trace	0.20	0.05	0.90	0.15	0.10	0.07½	....	....	....	....	....

two contained a trace and one had 0.025 per cent. It is regretted that tests were not made after the rowing on ordinary days, since it is probable that even this may have caused an appreciable albuminuria and that the traces found in the twenty-four-hour specimens really represented a considerable amount of albumin passed in one urination after rowing, diluted with non-albuminous urine passed during the rest of the day.

The renal conditions may be interpreted as an active hyperemia, becoming intense during the time-rows and races, and dependent in all probability on the increased arterial tension. Whether the hyperemia ever leads to permanent changes in the kidneys is a matter for future investigation.

The blood. — Numerous estimates of the specific gravity of the blood were made by Hammerschlag's method, with the intention of making blood counts and hemoglobin tests should any variation from the normal be observed. The method, however, was found to be tedious and unreliable, the results varying according to the temperature. In several instances when the specific gravity was low — 1.050 or thereabouts — a blood count and hemoglobin test gave normal figures. The examinations made yielded no information of importance and were therefore discontinued.

The digestive system. — One of the most troublesome features in training of all kinds is the care of the digestive organs. Many a race has been lost because of weak stomachs and because of prostration due to diarrhea. The crew squad this year offered no exception to this common tendency, for there were several cases of temporary attacks of indigestion and diarrhea. These troubles ought not to be attributed to the training but to improper diet and methods of eating. The food provided was all that could be de-

sired in quality and in preparation. The chief criticisms suggested were in regard to the selection of food by the men themselves and to their common habit of eating too much and too fast — faults not confined to crewmen but nevertheless unwise. The one aim of many of the men seemed to be to consume as much meat as they could get and in the shortest possible time. The amount of roast beef devoured at a single meal was astonishing, a man often disposing of five or six large slices.

It has already been pointed out in discussing variations in weight that the energy set free in muscular exercise is derived largely from the combustion of fat and carbohydrate material, while the proteid metabolism is directed chiefly to repairing waste. To use a rough illustration, if we regard the body as a machine, the proteid elements of the food go largely to replace the wear and tear of the machine itself, while the carbohydrates and fats furnish the fuel whose combustion liberates heat and energy and thus enables the machine to do work. Of course the body is not a machine and this comparison is not true except in a general way. During training the wear and tear of the body generally is much increased, and the proteid elements of the food must be increased accordingly, but it is an error to increase them so enormously as is frequently the case. The slight increase in the urea excretion indicates that much of the proteid material must pass through the digestive tract unassimilated. This throws a great deal of extra work upon the digestive organs, work which does no good to the body, but may, and undoubtedly often does, do harm in causing indigestion and diarrhea.

The subject is deserving of study based on analyses of the food and of the excretions. A more accurate adjustment of food to needs and more time spent in

mastication would unquestionably prevent that sensitiveness of the digestive organs which is one of the bugbears of the trainer.

III. OVER-TRAINING.

It was hoped that during this investigation data might be obtained bearing on the subject of over-training, but unfortunately (or fortunately, according to the point of view) there were no typical cases to study. The common symptoms are well known. They are, in brief, a loss of strength and endurance, so that a man previously strong becomes incapable of prolonged effort. This may be accompanied by a general nervous restlessness, by listlessness, by a loss of weight, by insomnia and by various digestive disturbances, such as anorexia and diarrhea. These symptoms should not be confounded with the temporary collapse which is occasionally seen after a severe exertion and which is more apt to be due to under-training than to over-training. The real condition at the bottom of over-training is still obscure, but in the light of this inquiry certain possibilities are suggested as factors which may have to do with its causation.

The first and most obvious one is the condition of the heart. We have seen that a great increase in size and strength is demanded of this organ and it may easily happen that it is called upon for more work than it is able to do and that instead of establishing a compensatory hypertrophy it becomes dilated and weakened. A "broken-winded" athlete is probably one with a dilated, flabby heart.

The second possible factor is the condition of nutrition. This is more difficult of demonstration than the first. As already pointed out, the nutrition may be disturbed in two ways, either by an improper diet, in which the nutritive elements are not apportioned to

the needs of the body, or by disturbed digestion, as a result of which the food taken into the body is not utilized. That both of these contingencies may occur has been sufficiently demonstrated.

The third factor may be simple overwork. This is not so likely as the two preceding, for, when properly nourished, the capacity for work on the part of healthy young men is certainly much greater than that demanded in training. The peculiarity of training work, however, is its concentration. It may be that the excessive work accomplished in a brief space of time exhausts the muscles so that they do not recuperate before being called upon for a repetition of the work — that there is, so to speak, an accumulation of fatigue, and that this constitutes over-training.

The fourth factor which suggests itself is a nervous one, and this, while more intangible than the others, is unquestionably an important one. In the present state of our knowledge it can only be surmised, not proved. It is well known that there is a nervous fatigue entirely distinct from muscular fatigue and resulting from prolonged anxiety, from monotony of work and from numerous other causes. It may be that anxiety about a coming contest, together with the prolonged mental strain of mastering the technicalities of such a difficult art as rowing or such a complicated game as football, may lead to a condition of nervous exhaustion, and that this nervous exhaustion contributes to over-training.

No one of these factors will account for all cases of over-training and probably more than one cause must be admitted. At any rate it is safe to suggest certain points which should be borne in mind in laying out any course of training. They are, (1) not to throw too much work upon the muscles and especially upon the heart, until they are strengthened by preliminary

work; (2) to watch the nutrition carefully, and (3) to avoid nervous fatigue by providing a certain variety of exercise, and by not confining the attention too closely to the approaching contest.

Finally, this investigation has demonstrated that the physiological effects of training, on the heart and kidneys in particular, may approach unpleasantly near to pathological conditions, and that there should be some competent supervision to insure that the safe limits, when those are determined, shall not be passed.